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Research Article

Agro-morphological variability in fourteen bambara groundnut (*Vigna subterranean* (L.) Verdc.) morphotypes cultivated in Niger.

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Abstract: Bambara groundnut (Vigna subterranea) is an indigenous grain legume that is adapted to a wide range of conditions and it is mainly grown by subsistence women farmers on a small scale, in pure culture without improved techniques. Bambara groundnut ranks third amongst tropical grain legumes in terms of production and consumption after groundnut (*Arachis hypognea*) and cowpea (*Vigna unguiculata* Walp.). The valorization of this culture is one of the best alternatives to ensure food security for populations facing declining production of food crops such as millet, sorghum or wheat. To achieve this goal, a better knowledge of the genetic diversity of this culture is more than necessary. The objective of this study was to investigate the agro-morphological characteristics of fourteen (14) Bambara groundnut morphotypes collected from the accessions that originated from Niger. The study was conducted on an experimental plot at Tara (Gaya Region) in the Sudanese agro-climatic area of the country. The trial was set up according to a randomized complete block design with four replications. Eighteen parameters were used to identify the morphotypes. The descriptive statistical analysis showed that the coefficients of variation ranging from 0% (color of the terminal leaflet, Shape of the terminal leaflet, Number of flower per flower stalk and Number of stem per plant) to 59.6% (number of pods per plant). Significantly higher values were observed (CV> 20%) to seven (7) of eighteen (18) analyzed parameters. The agromorphological characterization revealed that there is some significant mean differences between the morphotypes in terms of growth and development parameters (plant height and plants diameter) and yield components (pod weight/ plant, seeds weight / plant and number of pods /plant). The morphotypes, Ne-03, Ne- 04, Ne- 08, Ne-10 and Ne-12, showed the greatest performance for pod weight, seeds weight and number of pods /plant and its can be consider for selection for high yield per plant. The majority of correlations were significant (r > 0.32). This matrix showed that the most significant correlations were observed between the grain yield, pod weight, number of pods per plant, plant diameter and plant height. Our study indicated that the Grain yield per plant was positively correlated with the pod weight (r = 0, 99*) per plant, number of pods per plant (r = 0,82*), number of leafs per plant (r = 0,64*), plant height and plant diameter (r = 0,63*).
Keywords: *Vigna subterranea*, diversity, agromorphological, morphotypes, Niger

INTRODUCTION

Agricultural policy in developing countries focuses mainly on cash crops. This choice has not significantly improved the population's food situation. However, it has encouraged growers to abandon many local crops, which have declined as a result.

Because of their nutritional quality, these crops could have played a major role in providing a balanced diet for an ever increasing human population, but have been underexploited [1]. Their yields have therefore remained low and unstable. Bambara groundnut (Vigna subterranea) is an indigenous grain legume that is adapted to a wide range of conditions and it is mainly grown by subsistence women farmers [2, 3, 4, 5, 6] on a small scale, in pure culture without improved techniques. Bambara groundnut ranks third amongst tropical grain legumes after groundnut (*Arachis hypognea*) and cowpea (*Vigna unguiculuta*), Somta et al. [7]. It is a source of revenue for subsistence farmers and provides fodder for livestock and it is rich in protein. Bambara groundnut is also rich in carbohydrates and lysine [8, 9, 10, 11] and hence constitutes a balanced diet to the rural people that consume it as a sole or mixed with other meals. The leguminous plant is mainly grown for its underground seeds, which are eaten fresh, semi-ripe or as pulse when dry and mature or ground into flour for later use [1].

Bambara groundnut is used for soil fertilization with its binding capacity of atmospheric nitrogen and gives an average yields of 350 to 800 kg/ha in areas where the soil is poor and low rainfall [12, 6]. The average yield of Bambara groundnut at Niger is 458 kg/ ha over an area of 70,389 ha and a production of 32,266 T [13]. In addition, some morphotypes are resistant to insects, diseases and harsh drought conditions [14, 6]. The popularisation of Bambara groundnut cultivation and increasing its production could provide farmers with a substantial income and contribute to food safety in Africa [15, 1]. Research on Bambara groundnut has been very limited compared with investigation made on sorghum, millet, maize, peanut and cowpea [16]. However, in Niger, very little information is currently available about genetic diversity, culture and uses of Bambara groundnut in major production areas. A collection of bambara groundnut accessessions have done through the country [17]. As Morphological characterization represents the first stage of the investigation of a collection of genetic resources, therefore the objective of this study is to evaluate the phenological and agromorphological characteristics of Bambara groundnut morphotypes cultivated in Niger.

MATERIALS AND METHOD

MATERIALS

The plant material consisted of the seeds of 14 morphotypes (pic. 1) sorted from the accessions of the collection conducted in 2012-2013 at Niger [17].

Picture-1: Presentation of Bambara groundnut morphotypes (14) identified in Niger

METHOD

The evaluation of the morphotypes was done during the rainy season in 2004 at the National Institute for Agricultural Research (INRAN) station, located in the region of Gaya (289 km south East of Niamey), the Sudanese agro-climatic area of the country. The study site was located in the village of Tara (latitude: 11 ° 56'46 " N, longitude: 03 ° 19'53''E about 12 km from the urban district of Gaya.

A complete randomized blocks design was applied with 4 replications. In each block the seeds were sown in a ploughed sandy soil on rows spaced 40 cm. Intra-rows were spacing 2O cm. Each row was 1, 6 m long and each accession occupied one row (9 seeds per morphotype were sown per row). Each block was measured at 1.6 m wide (0.2m x 8) and 5.2 m long (0.4m x 13), an area of 8.32 m^2.

Eighteen (18) characters were used to assess the variability of Bambara groundnut morphotypes: Days to first flowering (DFF), 50% Days of Flowering (50% DF), Color of the terminal leaflet (CTeLt), Shape of the terminal leaflet (Shap TeLt), Number of flower per flower stalk (NF/FSk), Number of leaves (NLeaf), Number of stems per plant (Nst/Pt), Number of branches per stem (Nbr/st), Number of nodes per branch (Nnod/br), Plant diameter (cm) (PtD), Plant height (cm) (PtH), Number of pod per plant (Pod/Pt), Pod Length (mm) (PodL), Pod Width (mm) PodW), Seed Length (mm)(SL), Seed Width (mm) (SW), Dry pods weight (g) (DrpodWt), Grain Yield /Plant (g) GrY/Pt). Observations on the 18 characters were made according to Descriptors of bambara groundnut [18].

Data Analysis

The data for each trait were subjected to the descriptive statistical and an analysis of variance using the R Core Team R: A language and environment for statistical computing software [19] according to the randomized complete block design. The last significant difference (LSD) at P = 0, 05 was used to evaluate the significant differences between morphotypes. Simple correlation analysis (Pearson correlation coefficient) was applied to estimate the relationship between the parameters.

RESULTS AND DISCUSSION

Descriptive statistical analysis

The study of local Bambara groundnut morphotypes was used to assess the current status of the diversity of the species in Niger. The results showed a significant differences between the minimum and maximum values of the parameters, including the number of leaves per plant, number of pods per plant, length of seed, pod weight, weight of the dried seeds. The coefficients of variation ranging from 0% (color of the terminal leaflet, Shape of the terminal leaflet, Number of flower per flower stalk and Number of stem per plant) to 59.6% (number of pods per plant).Significantly higher values were observed (CV> 20%) to seven (7) of eighteen (18) analyzed parameters (Table-1). Our results showed that the Coefficient of Variation (CV) obtained for the number of leaves per plant (48.45%) is lower than that obtained by Bonny et al. [20], (62.3%) who studied 101 accessions but higher than those obtained by Massawe et al. [21], (31.6%) using six (6) accessions. However, the CV obtained for the number of pods per plant (59.6%) is higher than that obtained by Bonny et al. [20], (47.7%) and Ouedraogo et al. [5] (27.68%), whose used 310 accessions. The CV of the Grain yield per plant obtained (48.4%) is higher than those found by Ouedraogo et al. [5] (26.61%). The height of the plants obtained ranged from 7 to 23 cm and is lower than that obtained in the similar studies by Zénabou et al. [22] to Cameroon from 10 accessions (mini 20 and max 38 cm) and Bonny and Djé [20] (mini 17,04 and max 32.00 cm). This important phenotypic variability should derive to the expression of high genotypic heterogeneity and/or to the environmental factors [23]. The generally very low or null Coefficient of Variation observed for the six traits indicated a high level of uniformity in the morphotypes used.

Agro morphological characterization of morphotypes

Evaluation of agro-morphological variability and its characterization are the first step in the assessment of genetic diversity. Previous studies have shown that the choice of 15 to 20 agronomic characteristics is very useful to assess bambara groundnut genetic diversity [24, 5, 23]. On this study, the agromorphological characterization was performed on the fourteen (14) morphotypes and eighteen (18) parameters were used. It was performed in two phases. The first phase was to measure the growth and development parameters. The second phase involved the evaluation of yield components have helped to highlight the productive capacity of the studied morphotypes.

Evaluation of growth and Development parameters

The average number of leaves varied from 38.9 to 56.8, the day of first flowering ranged from 33 to 36.3 days after sowing and the day of 50% Flowering varied from 36 to 40 days. The average diameter of the plant varied from 24.2 cm to 31.9 cm and the height of the plant parameter ranged from 12 to 17.7 cm. But the analysis of variance showed that there was no significant difference between the mean of five of the seven growth and development parameters analyzed. Two of these (diameter of plants and plant height) parameters have showed a significant difference between means. Growth evaluation has shown that plant height range from 12 – 17, 7 cm. The highest plants were observed for the morphotypes Ne-08, Ne-04 and Ne-14 with 17, 7 cm; 16, 4 cm and 16, 4 cm, respectively. The morphotypes Ne-08, Ne-09 and Ne-14; presented the largest diameters of plants with, 31, 9 cm; 31, 7 cm and 31, 55 cm, respectively (Table 2) .

This result was obtained in similar studies by Dje et al. [25], who have studied four (4) morphotypes and Touré et al. [6] from Ivory Coast using 15 morphotypes. However, some authors found that no significant difference between the means of these two parameters [21, 12, 1]. These authors reported that the average height of the plants of *Vigna subterranea* was 24.19 cm or ranged from 14.41 to 24.3 cm. The differences observed between morphotypes of *Vigna subterranea* should be due to the genotypic characteristics or environmental conditions.

Table-1: Descriptive statistics during the characterization and evaluation of the 14 morphotypes of Bambara groundnut cultivated in Niger

N°	Characters	Mean	SD	Min.	Max.	CV%
1	Days to first flowering (DFF)	34	1,44	33	40	3.5
2	Days to 50% flowering (50% DF)	37.07	1,71	36	40	3.7
3	Color of the terminal leaflet (CTeLt)	1,00	-	1	1	-
4	Shape of the terminal leaflet (Shap TeLt)	3	-	3	3	-
5	Number of flower per flower stalk (NF/FSk)	2	-	2	2	-
6	Number of leaves (NLeaf/Pt)	46,75	15,40	21	100	48.45
7	Number of stems per plant (Nst/Pt)	1.00	-	1	1	-
8	Number of branches per stem (Nbr/st)	6.689	1,40	3	12	19.2
9	Number of nodes per branch (Nnod/br)	5,43	1,20	3	9	20.8
10	Plant diameter (cm) (PtD) (cm)	27,82	5,90	4	50	17.7
11	Plant height (cm)	14.84	2,90	7,00	23,00	15.6
12	Number of pod per plant (Pod/Pt)	15.01	9,60	1	112	59.6
13	Pod Length (PodL) (mm)	18,82	3,20	10	30	16.1
14	Pod Width PodW) (mm)	12,86	1,80	8	19	13.4
15	Seed Length (SL) (mm)	12,03	4,09	8	100	33.4
16	Seed Width (SW) (mm)	7,75	1,29	4	13	14.6
17	Dry pods weight (DrpodWt) (g)	14,04	7,48	0,26	37,21	48.7
18	Grain Yield per plant (GrY/Pt) (g)	10,71	5,68	0,21	31,97	48.4

Table-2: Mean of seven agronomic characters of 14 morphotypes of Bambara Groundnut

Parameters / Morphotypes	**Nleaf**	**DFF**	**D50% F**	**PtH**	**PtD**	**Nbr/st**	**Nnod/br**
Ne-01	52,3	36,3	40,0	14,0 cdef	26,8 bcd	6,65	5,05
Ne-02	46,2	33,3	36,0	14,9 bcde	27,1 bcd	6,30	5,85
Ne-03	47,0	33,3	36,8	15,1 bcd	27,9 abcd	6,20	5,25
Ne-04	53,1	33,0	36,8	16,4 ab	30,3 ab	5,90	5,40
Ne-05	41,8	33,8	37,0	13,3 efg	24,2 d	5,95	6,35
Ne-06	39,5	33,5	36,8	13,2 fg	24,9 cd	7,00	4,90
Ne-07	38,9	33,5	36,0	12,0 g	24,9 cd	6,25	4,75
Ne-08	55,3	34,3	37,8	17,7 a	31,9 a	7,35	5,25
Ne-09	56,8	33,8	37,0	15,6 bc	31,7 a	7,45	5,20
Ne-10	44,1	34,5	37,0	16,2 ab	28,9 abc	7,25	4,80
Ne-11	44,1	34,8	38,0	14,8 bcde	28,9 abc	7,10	5,90
Ne-12	40,6	33,8	36,0	13,5 defg	25,6 cd	6,75	5,65
Ne-13	46,6	33,5	36,0	14,3 cdef	24,5 d	6,15	5,70
Ne-14	48,5	35,0	38,0	16,4 ab	31,5 a	7,35	5,95
Mean	46,8	34,0	37,1	14,8	27,8	6,7	5,4
F test	ns	ns	ns	***	***	ns	ns
LSD				1.9	3.4		

***** Significant at 5% level of significance ****** highly significant difference = P <0.01; ******* very highly significant difference = P <0.001, ns: non-significant difference. In the same column, the means followed by the same letter are statistically identical.

Evaluation yield related components of 14 morphotypes of Bambara Groundnut

The evaluation of yield components (Table 3) made it possible to determine the production capacities of the plants studied. It showed that the number of pods ranged from 8,1 to 19,2 ; the pod weight and weight of dried seeds ranged from 8.5 g to 18.7 g and 5.7 g to 14.3 g, respectively. The lower weight of pods, seeds and number of pods is observed at the morphotype Ne-01. The length of pods, pod width, length and width of seeds are higher in the morphotype Ne-08. No significant difference was observed between the mean of the four parameters of seven yield components analyzed. These are pod length parameters, width of pods, lengths and width of seeds. A significant difference was observed for the three parameters, namely the number of pods, weight of pods and grain yield per plant. The number of mature pods in the morphotypes Ne-12, Ne-02, Ne-03, Ne-04, Ne-07, Ne-09, Ne-10, Ne-13 was statistical equal and greater than those for other morphotypes. The morphotype Ne-04 showed the greatest seeds weight (14,4 g/Pt) followed by Ne-03 (12,9 g), Ne-12 (12,3 g), Ne-08 (12,1 g) and Ne-10 (12,1 g), while the lowest grain yield was obtained from the morphotype Ne-01 (5,7 g). The morphotype Ne-12 showed the greatest seed length and seed width. The smallest seed length was observed in the morphotype Ne-05 with the smallest seed width (Table 3). The yield components analysis showed that the means of three (pod weight per plant, number of pods per plant and grain yield per plant) of seven parameters studied were significantly different between morphotypes. This is in agreement with the findings of a similar study by Massawe et al. [21] in six (6) morphotypes at Botswana and Djé et al. [25] in four accessions at Ivory Coast. The average number of pods per plant is lower than those reported by Touré et al. [6], with fifteen (15) morphotypes, but the Grain yield per plant is higher than those found by Touré et al. [6]. This author reported that the average number of pods per plant in *Vigna subterranea* varied from 18 to 47 and that of the Grain yield per plant from 0.43 to 0.81g. The difference between these results could be explained by the difference between the morphotypes, the soil fertility of land and local climate.

Table-3: Mean of yield components of 14 morphotypes of Bambara Groundnut cultivated in Niger

Parameters / Morphotypes	Npod/Pt	PodWt/Pt (g)	GrY/Pt (g)	PodL (mm)	PodW (mm)	SL (mm)	SW (mm)
Ne-01	8,1 c	8,5 d	5,7 e	17,97	13,32	11,29	7,88
Ne-02	15,6 ab	13,8 bc	10,1 bcd	18,77	12,68	11,55	7,43
Ne-03	17,0 ab	17,0 ab	12,9 ab	19,58	12,85	11,58	7,6
Ne-04	14,7 ab	18,7 a	14,3 a	20,2	13,25	13,25	9,07
Ne-05	13,9 b	10,8 cd	8,5 cde	18,05	12,48	10,87	7,13
Ne-06	12,7 bc	10,4 cd	8,0 de	17,18	12,37	13,7	7,43
Ne-07	16,3 ab	12,7 bcd	9,7 bcd	17,48	11,85	11,33	7,27
Ne-08	12,2 bc	16,5 ab	12,1 abc	21,28	14,25	14,38	9,38
Ne-09	14,4 ab	15,7 ab	11,9 abc	19,3	12,7	12,3	8
Ne-10	16,8 ab	16,0 ab	12,1 abc	18,92	12,93	12,05	7,55
Ne-11	14,0 b	13,3 bc	10,1 bcd	19,15	12,88	11,41	7,35
Ne-12	19,2 a	14,8 abc	12,3 ab	18,35	12,45	11,45	7,45
Ne-13	14,6 ab	13,0 bcd	10,1 bcd	17,37	12,85	11,38	7,53
Ne-14	13,9 b	15,04 abc	10,7 abcd	19,75	13,33	11,75	7,5
Mean	14,6	14,0	10,6	18,82	12,86	12,03	7,75
F test	*	**	**	ns	ns	ns	ns
LSD	3,0	494.6	367.3				

***** Significant at 5% level of significance ****** highly significant difference = P <0.01; ns: non-significant difference. In the same column, the means followed by the same letter are statistically identical.

Correlations Among parameters

Correlation coefficient is important in plant breeding in that it measures the degree of association, genetic or non genetic between two or more characters [5]. Adebisi et al. [26] reported that crop improvement depends upon the magnitude of genetic variability present in the base population and once genetic variability has been ascertained in a crop, improvement is possible by using an appropriate selection method. This involves the knowledge of correlation between traits and yield [27, 28]. Correlation studies between traits have been of great value in determination of the most effective procedures for selection of superior genotype [26, 28].

The correlation coefficients (r) between the various characters were presented in Table 4. The majority of correlations were significant (r > 0.32). This matrix showed that the most significant correlations were observed between the grain yield, pod weight, number of pods per plant, plant diameter and plant height. Our study indicated that the Grain yield per plant was positively correlated with the pod weight (r = 0, 99*) per plant, number of pods per plant (r = 0,82*),

number of leafs per plant (r = 0,64*), plant height and plant diameter (r = 0,63*). Jonah [28] also well reported that pod yield/plant recorded a positive correlation coefficient with seed yield/plant (r = 0,95**) and seed yield/ha (r = 0,65**). This agrees with the findings of Kadams and Sajo [29] in Bambara groundnut and Ariyo et al. [30] in okra (*Abelmoschus esculentus* L. Moench. Our results showed that the seed yield/plant is positively correlated to all the morphological parameters as found Touré et al. [6]. The plant height was significantly correlated with the number of leafs (r = 0, 67) and plant diameter (r = 0, 81). A negative correlation appeared between grain weight per plant (r = - 0, 27), pod weight per plant (r = -0, 23) and 50 % flowering date [23]. The correlations between the parameters revealed that all the morphotypes which great plant height and higher number of leaves have a higher diameter, number of pods per plant, pod weight per plant and a higher grain yield per plant. Similar observations were reported by Bonny and Djé [20] with 101 accessions studied and Touré et al. [6] with fifteen morphotypes. However, these observations have not been confirmed by the work of Ouedraogo [5] and Abu and Buah [31].

Table-4: Correlation coefficients of Pearson among the agro morphological traits in bambara groundnut morphotypes cultivated in Niger

	Nleaf	**DFF**	**D50%F**	**PtH**	**PtD**	**Nbr/ st**	**Nnod/ br**	**Npod/ Pt**	**PodWt/ Pt**	**GrY/ Pt**
Nleaf	-									
DFF	0,03	-								
D50% F	0,08	0,74*	-							
PtH	0,67*	-0,04	0,01	-						
PtD	0,72*	0,06	0,06	0,81*	-					
Nbr/st	0,03	0,07	0,10	0,11	0,21	-				
Nnod/br	0,04	-0,06	-0,04	0,09	0,10	0,04	-			
Npod/Pt	0,52*	-0,18	-0,30	0,32*	0,39*	-0,03	-0,01	-		
PodWt	0,71*	-0,19	-0,23	0,69*	0,70*	0,09	0,04	0,79*	-	
GrY/Pt	0,64*	-0,22	-0,27	0,63*	0,63*	0,10	0,05	0,82*	0,99*	-

***** Significant correlation at p = 0.05

CONCLUSION

The study revealed an agro-morphological variability between the fourteen (14) Bambara groundnut morphotypes. Including parameters such as the number of leaves per plant (CV = 48.45%), number of pods per plant (CV = 59.6%), seeds weight per plant (CV = 48.4%), pod weight per plant (CV = 48.7%), length of seeds (CV = 33.4%). The agromorphological characterization revealed that there is some significant mean differences between the morphotypes in terms of growth and development parameters (plant height and plants diameter) and yield components (pod weight/ plant, seeds weight / plant and number of pods /plant). The morphotypes, Ne-03, Ne- 04, Ne- 08, Ne-10 and Ne-12, showed the greatest performance for pod weight, seeds weight and number of pods /plant and its can selected for high yield per plant. Agronomic and morphological evaluations have provided more accurate estimation of genetic diversity, the raw material of plant breeding. Our aim is to increase yield of Bambara groundnut in Niger so according to the correlation matrix, we can focus our selection on high number of pods per plant (Npod/Pt), pod weight per plant (PodWt/Pt), plant height (PtH), plant diameter (PtD) and number of leaves, parameters with significant correlation with the Grain yield per plant (GrY/Pt).

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